Analysis of the Iberian Power Forward Price Formation

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***Abstract*—The price formation of the Iberian Energy Derivatives Market—the power futures market—starting in July 2006, is assessed until November 2011, through the evolution of the difference between forward and spot prices in the delivery period ("ex-post forward risk premium") and the comparison with the forward generation costs from natural gas ("clean spark spread"). The premium tends to be positive in all existing mechanisms (futures, Over-the-Counter and auctions for catering part of the last resort supplies). Since year 2011, the values are smaller due to regulatorily recognized prices for coal power plants. The power futures are strongly correlated with European gas prices. The spreads built with prompt contracts tend also to be positive. The biggest ones are for the month contract, followed by the quarter contract and then by the year contract. Therefore, gas fired generation companies can maximize profits trading with contracts of shorter maturity.**

***Index Terms*—Business, energy management, finance, power industry.**

I. INTRODUCTION

THIS research analyses the price formation of the Iberian energy derivatives market, the power futures market managed by OMIP (Iberian Energy Market Operator, Portuguese Pool), through two key indicators: 1) the ex-post forward risk premium, obtained as the difference of the average forward price during the quotation period of the contract and the resulting average spot price during the delivery period (e.g., [1] and [2]); 2) the clean spark spread, obtained as the difference between the power futures price and the forward generation cost with a gas fired combined cycle plant taking into account the CO_2 emission rates (e.g., [3]).

This power futures market started its operations on July 3, 2006. The data set considers the first five years and five months (until November 30, 2011). For power futures prices, OMIP settlement prices for base load contracts with underlying price the spot price of the Spanish zone are considered. Such contracts are identified as "FTB" (Futures Base Load). For power spot prices, OMIE (Iberian Energy Market Operator, Spanish Pool) daily prices are calculated as the arithmetical average of the hourly prices in the day-ahead auction for each day. For gas prices, Platts' assessments of transactions traded OTC (Over-the-Counter, i.e., out of organized markets) in the Dutch virtual trading point (Title Transfer Facility, "TTF") are used. The Spanish gas market lacks of price transparency, as physical swaps for balancing purposes are arranged amongst participants without disclosing the price [4]. Therefore the most liquid reference in continental Europe, as indicated in [5], has been taken instead. For the CO_2 emissions, EUA (European Union Allowances) futures settlement prices in the ICE (InterContinelExchange) derivatives exchange are used. Brent crude oil prices—both spot prices assessed by Platts and ICE futures—are considered to analyze its correlation with gas prices and co-integration relationships with power prices.

In order to understand the utilization of energy derivatives, a section is provided describing the fundamentals of forward energy trading. For the comprehension of the performance of the Iberian energy derivatives market, a section is provided describing its trading development and its interaction with other electricity forward market mechanisms. Afterwards, the ex-post forward risk premia and the clean spark spreads are analyzed. Correlation and co-integration analyses are done to understand the relationships between the different energy prices and their impact in the electricity price formation. Finally, the article concludes stating the main findings and suggesting further research work.

II. FUNDAMENTALS OF FORWARD ENERGY TRADING

The liberalization process in the energy sector and the determination of spot prices through market mechanisms have produced the development of forward contracting. Derivatives are widely used, as their main function is the risk management [6]. Derivatives are financial instruments whose characteristics and value depend upon the characteristics and value of an underlying product (e.g., the electricity spot price) [7]. Forward markets play an important role as a mechanism for transferring risk and in the process of gathering information that leads to price discovery. If two agents who are exposed to the same risk but hold opposite positions [e.g., a power generation company (usually a seller) and a large industrial firm (usually a buyer)] wish to reduce their exposure to future spot price fluctuations, they will be interested in doing a forward transaction. Those agents less/more tolerant to risk may be willing to pay/receive a premium to reduce/increase their risk exposure. Forward trading can take place in futures markets (subject to regulation) or in OTC markets. To reduce counterparty search costs and increase liquidity, the OTC markets can be organized around brokers. In the case of futures markets, the central clearing house bears the counterparty risk, as it becomes the seller to every buyer, and the buyer to every seller [8]. Hedging eliminates financial difficulties produced by adverse price movements. Hedging can have a positive effect on the financial stability of utilities that use forward markets to protect their spot positions [9]. Every market participant should assess the benefits of participating in forward markets (e.g., for portfolio hedging or arbitrage/speculation gains) against the inherent costs (e.g., brokerage/clearing house fees, and credit line/collateral requirements).

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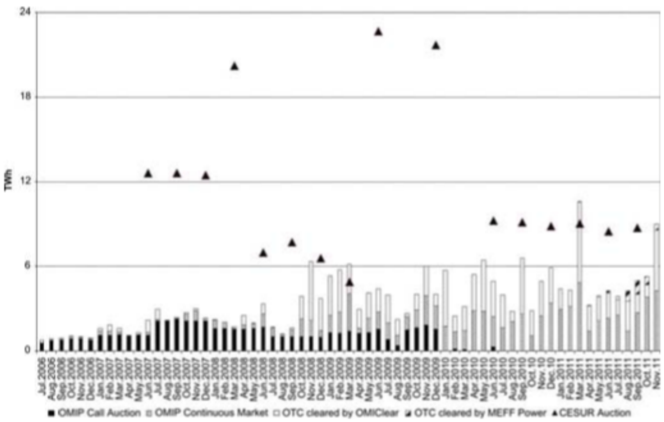

Fig. 1. Evolution of traded and cleared volumes in OMIP-OMIClear, cleared volumes in MEFF Power, and matched volumes in CESUR auctions (TWh). Sources: [10], [11], and [12].

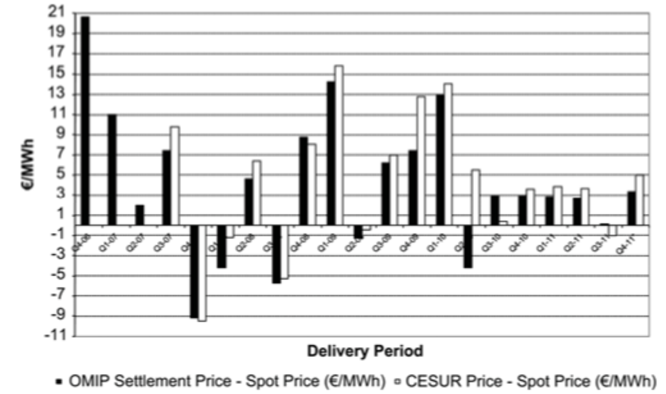

Fig. 2. Evolution of the ex-post forward risk premia in the Iberian energy derivatives exchange and in CESUR auctions. Sources: [10], [11], and [18] adapted by authors. ∗ Data for Q4-11 span from October 1 to November 30.

III. Overview of the Trading Development in the Iberian Power Forward Contracting Mechanisms

The evolution of OMIP traded volumes has to be seen in conjunction with the dominant non-organized OTC market and with the CESUR (Contracts of Energy for the Last Resort Supply) auctions. The OTC market reflects, in Spain, financial trading either bilaterally or with the intermediation of brokers, being a portion of them cleared and settled through clearing houses. The CESUR auctions are regulated auctions catering for part of the Spanish last resort supplies. The auction price is used as the estimated forward energy cost in the price formula for the last resort tariff [8] and [9]. Fig. 1 shows the evolution of the cleared and settled volumes (in TWh) in OMIClear (OMIP clearing house) through bars, and the matched volumes in CESUR auctions through triangles. There are two market modes in OMIP: the continuous market and auctions. Whereas the former is the main mode, the latter has performed a key role in the development of the liquidity in OMIP, as the Spanish distribution companies and the Portuguese last resort supplier were obliged to purchase energy in such auctions until July 2009 and July 2010 respectively. Furthermore OMIClear permits the clearing and settlement of OTC volumes by OMIP trading members. In the period June 2007–November 2011, 16 CESUR auctions have been celebrated [10], [11].

OMIP traded volumes in the first two years were led by the compulsory auctions. During 2010, the scarce auction volumes were generated by compulsory auctions of peak futures for the Portuguese last resort supplier. OMIP peak futures are still very illiquid. The month with record of continuous volumes was March 2011 (4.86 TWh). The OTC cleared volumes also reached a record in that month (5.68 TWh) and maintained a growing trend, influenced by the OTC trading development. Since March 21, 2011, OTC power trades with Spanish underlying spot prices can also be cleared and settled in another clearing house: MEFF Power (MEFF stands for Spanish Financial Futures Market). Although its number of enrolled members is growing fast—24 at the end of November 2011, of which 13 are also active in OMIP, which has 35 members at that date—the registered volumes until the end of November 2011 are still small (3.3 TWh) compared to OTC registered volumes in OMIClear in the period March 2011–November 2011 (20.6 TWh) [10], [12]. The first 16 CESUR auctions account for a traded volume of 182.2 TWh, 19% less than the volumes cleared by OMIClear in the period July 2006–November 2011 [11]. The OTC market has experienced a steady growing trend, summing up in that period approximately 837.5 TWh [13]. Only a minor part of the OTC volumes is cleared and settled by the existing clearing houses (10% by OMIClear and 1% by MEFF Power) [10], [12].

IV. Evaluation of the Ex-Post Forward Risk Premia in the Iberian Energy Derivatives Exchange and in the Cesur Auctions

A. Analysis of the Forward Risk Premium

The ex-post forward risk premium ("$\mathbf{FRP_{ex-post}}$") is mathematically expressed in (1) as follows:

$$FRP_{ex-post} = F_{t,T} - Average(S_T) \tag{1}$$

where "$\mathbf{F_{t,T}}$" refers to the power futures price on day "t" for delivery over period "T" and "Average $(\mathbf{S_T})$ refers to average spot price for delivery over period T [1], [2], [8].

Reference [14] shows, through analysis of forward and spot data in the German power market (European Energy Exchange, EEX), that the forward premium in electricity is a function of fundamental, behavioral, dynamic, market conduct and shock components. This premium is influenced by the gas prices, the oil price volatility, the generators' market power and the power scarcity. They suggest to use this premium as a market monitoring indicator as higher premium could be caused by market concentration.

Fig. 2 shows the evolution of the ex-post forward risk premium in the Iberian energy derivatives exchange and in the CESUR auctions. For OMIP prices, the average settlement price of the prompt quarter futures contract in its last month of quotation is employed. The CESUR price corresponds to the equilibrium price of the prompt quarter base load forward contract in the auction celebrated immediately before the delivery of such a contract. The price efficiency has improved with the development of the futures market, as the forward risk premia evolve towards smaller values. However, positive values tend to dominate in all the existing forward contracting mechanisms. The OTC, futures and CESUR prices are all interrelated and thus are very close [8], [15], [16], [17].

Reference [19] analyses OMIP forward risk premia (data from July 2006 to February 2010) and shows differences per contract maturity, allowing arbitrage gains through combined trading of the month, quarter and year futures contracts. Arbitrage opportunities also arise between OMIP and CESUR due to the differences in their equivalent premia. Year futures contracts show the largest ex-post forward risk premium, followed by quarter contracts and then by month contracts. Due to that fact and the dominance of positive forward risk premia, natural sellers may be more interested in trading contracts with larger maturity (year and quarter) and conversely, natural purchasers may be more interested in trading month futures contracts. The large positive premia during 2009 and the first quarter of 2010 are caused by rising forward prices and decreasing spot prices in the Iberian energy market. The former were pushed up by the uncertainty in global financial markets, tight credit conditions and price increases in energy commodity prices. The latter were decreased by the depressed economic situation and low prices in the power pool with reduced demand and strong penetration of renewables. The smaller spot prices were also influenced by large rainfalls and the effect of gas take-or-pay contracts [20].

The positive forward risk premia in the CESUR auctions are usually bigger than in OMIP. The smaller premia during year 2011 are influenced by new regulation affecting the spot price formation and accordingly the forward price levels. The Royal Decree 134/2010, of 12 February 2010, compelling the Spanish coal power plants to burn indigenous coal at a regulated price for the sake of security of supply, in force in February 2011, fixes the generation costs of 10 coal power plants. For the year 2011, the variable cost of the coal plant with biggest production is around 53 €/MWh, being the weighted average price of the 10 plants, according to their maximum allowed volumes, equal to 55.30 €/MWh—setting a price threshold in the merit order curve of the spot market [21], [22].

B. Impact of Renewable Penetration on Wholesale Prices

Reference [23] provides a comprehensive literature review and assessment of studies of the impact of wind energy on electricity prices, built with case studies of Germany, Denmark, and Belgium. An increased penetration of wind power reduces CO_2 emissions as well as the wholesale spot and end-user prices. Wholesale electricity prices are reduced between 3 and 23 €/MWh depending on the amount of wind power. Wind replaces hard coal power plants during hours of low demand and gas-fired power plants during hours of high demand in the countries analyzed. The low marginal costs of wind generation push more expensive technologies, such as gas and thermal plants, out of the market (the "merit order effect" in the matching of the supply and demand curves).

Reference [24] analyses ex-post the effects of special regime generation (i.e., renewable sources, waste heat and co-generation) on Spanish wholesale electricity prices, with data for years 2005–2009. A marginal increase of 1 GWh of special regime generation is associated with a reduction of almost 2 €/MWh (ca. 4%) in wholesale power prices.

More accurate production forecasts for intermittent renewable sources (wind and solar) could produce a downward pressure in the short-term prompt forward prices, contributing to lessen their forward risk premia.

V. Evaluation of the Forward Generation Costs

The Combined Cycle Gas Turbine (CCGT) generation accounts in Spain in 2009 for 24% of the installed capacity and for 29% of the electricity gross production, being the main generation technology [25]. In order to understand the power forward price formation, correlation analyses—between power, gas and emission prices as well as between oil and gas prices—co-integration analyses of power, gas and oil prices, and tracking of the clean spark spreads are performed.

The main fundamentals for the Spanish electricity forward price formation are the expected demand, the CO_2 allowances prices, and the fuel forward prices (especially the natural gas) [15]. The evolution of the spot price and the neighboring power prices (France and Germany) should also be taken into account [16]. The Brent crude oil and natural gas forward prices play a prominent role in the Spanish electricity forward price formation process [9]. That research considers prompt month forward contracts and uses the gas prices of the Belgian gas hub, located at Zeebrugge, due to the commented lack of local reference for the Spanish gas market. The power, oil and gas series are co-integrated (the three markets respond to common information). The series of Spanish electricity forward prices adjusts to past disequilibria by moving toward the trend values of oil and gas prices. There is a short-run bidirectional relation between oil and gas forward prices. There are volatility spillovers from the oil and gas markets to the Spanish electricity market as well as between the two fuels markets. Any shock or increase in volatility originated in the oil and gas forward markets should be taken into account by market participants in the Spanish electricity forward market in order to anticipate a volatility rise in this market.

A. Correlation Analysis

Table I shows the correlations between daily power prices [OMIE spot price, OMIP futures prices for the prompt month ("$M+1$"), quarter ("$Q+1$") and year ("$Y+1$") contracts], daily gas prices (TTF spot and forward $M+1$, $Q+1$ and $Y+1$ contracts), and daily CO_2 emission allowances (futures prices for the most liquid contract: the prompt December contract "$Dec+1$"). Different sub-periods have been considered to take into account significant events affecting the price formation, namely: (Period 1) July 3, 2006–May 31, 2007 (as since June 2007, the application of a fixed price of 42.35€/MWh in the power pool for intra-group bilateral transactions expire [26] and [27]); (Period 2) June 1, 2007–November 30, 2007 (as the second phase of the European Union Emissions Trading System (EU ETS) (2008–2012) begins in December 2007 [28]); (Period 3) December 3, 2007–August 29, 2008 (as September 2008 represents the beginning of the effects of the global financial crisis on the real economy [9]); (Period 4) September 1, 2008–January 31, 2011 (as the Royal Decree 134/2010 entered in force in February 2011 [21] and [22]); (Period 5) February 1, 2011–November 30, 2011. Correlation results are also shown for the whole data set.

In general, the CO_2 prices show the smallest correlation, even with negative correlation especially in Period 2 due to near to zero price values of the emission allowances at the end of the first phase of the EU ETS and in Period 5 as the emission rates present a steady decline from April 2011 (quoting around 18 $€/tCO_2$) until November 2011 (quoting around 8 $€/tCO_2$). High correlation is observed amongst all the gas and power forward prices of same maturity (especially $Q+1$ and $Y+1$). The electricity spot prices tend to show negative correlation with gas and CO_2 prices in Period 3, in which record oil prices are registered.

TABLE I
CORRELATION MATRIX BETWEEN WHOLESALE ENERGY PRICES. SOURCES: OMIP-OMICLEAR, PLATTS, AND ICE

	Spot Electricity	M+1 Electricity	Q+1 Electricity	Y+1 Electricity	Spot Gas	M+1 Gas	Q+1 Gas	Y+1 Gas	Dec+1 CO_2
Period 1: 3 July 2006- 31 May 2007									
Spot Electricity	1.00	0.73	0,62	0.65	0.47	0.44	0.58	0.65	0.68
M+1 Electricity	0.73	1.00	0.84	0.75	0.61	0.66	0.74	0.67	0.79
Q+1 Electricity	0,62	0.84	1.00	0.77	0.65	0.72	0.86	0.79	0.86
Y+1 electricity	0.65	0.75	0.77	1.00	0.42	0.45	0.60	0.64	0.66
Spot Gas	0.47	0.61	0.65	0.42	1.00	0.81	0.79	0.67	0.77
M+1 Gas	0.44	0.66	0.72	0.45	0.81	1.00	0.89	0.58	0.78
Q+1 Gas	0.58	0.74	0.86	0.60	0.79	0.89	1.00	0.86	0.96
Y+1 Gas	0.65	0.67	0.79	0.64	0.67	0.58	0.86	1.00	0.92
Dec+1 CO_2	0.68	0.79	0.86	0.66	0.77	0.78	0.96	0.92	1.00
Period 2: 1 Jun 2007 - 30 November 2007									
Spot Electricity	1.00	0.74	0.69	0.73	0.51	0.47	0.36	0.61	-0.18
M+1 Electricity	0.74	1.00	0.74	0.84	0.31	0.31	0.12	0.54	0.02
Q+1 Electricity	0.69	0.74	1.00	0.87	0.72	0.79	0.64	0.89	-0.31
Y+1 electricity	0.73	0.84	0.87	1.00	0.54	0.56	0.42	0.80	-0.07
Spot Gas	0.51	0.31	0.72	0.54	1.00	0.97	0.92	0.88	-0.65
M+1 Gas	0.47	0.31	0.79	0.56	0.97	1.00	0.94	0.90	-0.65
Q+1 Gas	0.36	0.12	0.64	0.42	0.92	0.94	1.00	0.81	-0.71
Y+1 Gas	0.61	0.54	0.89	0.80	0.88	0.90	0.81	1.00	-0.45
Dec+1 CO_2	-0.18	0.02	-0.31	-0.07	-0.65	-0.65	-0.71	-0.45	1.00
Period 3: 3 December 2007 - 29 August 2008									
Spot Electricity	1.00	0.54	0.04	0.08	-0.21	-0.20	-0.20	-0.03	-0.33
M+1 Electricity	0.54	1.00	0.21	0.30	0.05	0.23	0.40	0.28	0.14
Q+1 Electricity	0.04	0,21	1.00	0.87	0.39	0.60	0.90	0.83	0.63
Y+1 electricity	0.08	0.30	0.87	1.00	0.44	0.68	0.89	0.98	0.73
Spot Gas	-0.21	0.05	0.39	0.44	1.00	0.78	0.34	0.52	0.72
M+1 Gas	-0.20	0.23	0.60	0.68	0.78	1.00	0.62	0.77	0.91
Q+1 Gas	-0.20	0.40	0.90	0.89	0.34	0.62	1.00	0.86	0.60
Y+1 Gas	-0.03	0.28	0.83	0.98	0.52	0.77	0.86	1.00	0.82
Dec+1 CO_2	-0.33	0.14	0.63	0.73	0.72	0.91	0.60	0.82	1.00
Period 4: 1 September 2008 - 31 January 2011									
Spot Electricity	1.00	0.94	0.90	0.87	0.77	0.84	0.86	0.82	0.71
M+1 Electricity	0.94	1.00	0.97	0.93	0.81	0.89	0.93	0.87	0.81
Q+1 Electricity	0.90	0.97	1.00	0.94	0.74	0.84	0.93	0.87	0.89
Y+1 electricity	0.87	0.93	0.94	1.00	0.76	0.83	0.88	0.93	0.84
Spot Gas	0.77	0.81	0.74	0.76	1.00	0.96	0.87	0.79	0.58
M+1 Gas	0.84	0.89	0.84	0.83	0.96	1.00	0.94	0.85	0.69
Q+1 Gas	0.86	0.93	0.93	0.88	0.87	0.94	1.00	0.89	0.83
Y+1 Gas	0.82	0.87	0.87	0.93	0.79	0.85	0.89	1.00	0.78
Dec+1 CO_2	0.71	0.81	0.89	0.84	0.58	0.69	0.83	0.78	1.00
Period 5: 1 February 2011 - 30 November 2011									
Spot Electricity	1.00	0.63	0.45	0.30	-0.08	0.42	0.55	0.18	-0.57
M+1 Electricity	0.63	1.00	0.83	0.63	0.05	0.50	0.58	0.27	-0.63
Q+1 Electricity	0.45	0.83	1.00	0.90	0.21	0.56	0.62	0.56	-0.32
Y+1 electricity	0.30	0.63	0.90	1.00	0.33	0.55	0.68	0.75	-0.21
Spot Gas	-0.08	0.05	0.21	0.33	1.00	0.53	0.10	0.11	0.08
M+1 Gas	0.42	0.50	0.56	0.55	0.53	1.00	0.56	0.27	-0.34
Q+1 Gas	0.55	0.58	0.62	0.68	0.10	0.56	1.00	0.68	-0.53
Y+1 Gas	0.18	0.27	0.56	0.75	0.11	0.27	0.68	1.00	0.09
Dec+1 CO_2	-0.57	-0.63	-0.32	-0.21	0.08	-0.34	-0.53	0.09	1.00
Total (data set from July 3 2006 until November 30 2011)									
Spot Electricity	1.00	0.91	0.83	0.78	0.75	0.78	0.75	0.76	0.56
M+1 Electricity	0.91	1.00	0.93	0.87	0.77	0.83	0.81	0.83	0.59
Q+1 Electricity	0.83	0.93	1.00	0.91	0.75	0.83	0.88	0.89	0.54
Y+1 electricity	0.78	0.87	0.91	1.00	0.68	0.73	0.78	0.92	0.42
Spot Gas	0.75	0.77	0.75	0.68	1.00	0.94	0.81	0.76	0.53
M+1 Gas	0.78	0.83	0.83	0.73	0.94	1.00	0.90	0.80	0.51
Q+1 Gas	0.75	0.81	0.88	0.78	0.81	0.90	1.00	0.86	0.50
Y+1 Gas	0.76	0.83	0.89	0.92	0.76	0.80	0.86	1.00	0.56
Dec+1 CO_2	0.56	0.59	0.54	0.42	0.53	0.51	0.50	0.56	1.00

For the spot power price, the biggest correlation with the power futures prices is for the $M+1$ contract for all the sub-periods (0.91 for the whole data set) as the time proximity is the biggest one. Equally, for the spot gas price, the biggest correlation is for the $\mathrm{M}+1$ forward gas price for all the sub-periods (0.94 for the whole data set). Although the correlation amongst all the futures power prices in the whole data set is bigger than 0.8, only $\mathrm{Q}+1$ and $\mathrm{Y}+1$ contracts present a correlation bigger than 0.75 in all the sub-periods. In the same way, the correlation amongst all the forward gas prices is bigger than 0.8, but in Period 5, characterized by much uncertainty in the global economic recovery, the $\mathrm{M}+1$ contract shows small correlation values with the $\mathrm{Q}+1$ (0.56) and $\mathrm{Y}+1$ (0.27). The prompt month and quarter futures power contracts show correlation bigger than 0.8 with all the gas forward contracts in the whole data set, though falling to much smaller values when considering sub-periods. The biggest correlation between futures power and forward gas prices is between the year contracts (0.92 for the whole data set, falling to 0.64 in Period 1) as the long-term futures power prices are closely influenced by the evolution of commodity prices (oil, gas and coal) as long as the scope of renewable forecasts is for the very short term. Although the emission allowances are influenced by the evolution of power and fuel prices, no high correlation values are obtained due to the excess of offer in the EU ETS (the Member States grant for free a quota of emission allowances to the polluting industries), provoking transitorily decoupled low emission prices and eventually near to zero values [28].

TABLE II
CORRELATION BETWEEN GAS PRICES (TTF, IN €/MWh) AND OIL PRICES (BRENT,$/BBL). SOURCES: PLATTS AND ICE

	Brent Spot	Brent M+1	Brent M+3	Brent M+6	Brent M+9	Brent M+12
Period 1: 3 July 2006 - 29 August 2008						
TTF Gas Spot	0.80	0.80	0.79	0.78	0.78	0.77
TTF Gas M+1	0.69	0.70	0.70	0.70	0.70	0.70
TTF Gas Q+1	0.57	0.59	0.60	0.61	0.61	0.61
TTF Gas Y+1	0.84	0.86	0.87	0.89	0.90	0.90
Period 2: 1 September 2008 - 30 June 2009						
TTF Gas Spot	0.39	0.42	0.46	0.49	0.50	0.51
TTF Gas M+1	0.48	0.50	0.54	0.57	0.59	0.59
TTF Gas Q+1	0.62	0.64	0.68	0.70	0.71	0.72
TTF Gas Y+1	0.86	0.87	0.89	0.90	0.91	0.91
Period 3: 1 July 2009 - 30 November 2011						
TTF Gas Spot	0.79	0.79	0.79	0.78	0.77	0.77
TTF Gas M+1	0.83	0.82	0.81	0.80	0.80	0.79
TTF Gas Q+1	0.84	0.83	0.82	0.81	0.81	0.80
TTF Gas Y+1	0.88	0.87	0.86	0.85	0.85	0.84
Total data set (from July 3 2006 to November 30 2011)						
TTF Gas Spot	0.60	0.61	0.62	0.62	0.62	0.62
TTF Gas M+1	0.56	0.57	0.58	0.58	0.58	0.58
TTF Gas Q+1	0.54	0.56	0.57	0.58	0.58	0.58
TTF Gas Y+1	0.66	0.67	0.69	0.70	0.70	0.70

The gas prices are influenced by the evolution of fundamental variables, linked to supply and demand (e.g., cold snaps, availability of interconnectors and Liquefied Natural Gas (LNG) carriers, stock levels at the underground storages and regasification plants), as well as the macroeconomic situation and the evolution of the exchange rates ($/€) and oil prices. The oil prices are still the main component in the indexed formulas of the majority of long term gas contracts in Europe [16], [29], [30], [31]. Table II shows the correlation of gas prices (at TTF) with crude oil prices (Brent spot and futures prices, assessed by Platts and quoted at ICE, respectively). Different sub-periods have also been considered: (Period 1) July 3, 2006–August 29, 2008 (as September 2008 represents the beginning of the effects of the global financial crisis on the real economy [9]); (Period 2) September 1, 2008–June 30, 2009 (as TTF increases its liquidity since July 2009 due to introduction of "quality conversion", permitting gas trading gas irrespective of its High or Low Calorific nature [5]); (Period 3) July 1, 2009–November 30, 2011. The prompt year gas prices present the biggest correlation with oil prices (around 0.70 for the whole data set). In general, there is high correlation between oil and gas prices for all the sub-periods analyzed and the lowest values occur in Period 2.

The correlation between energy prices for the prompt month, quarter, and year contracts can be appreciated in Figs. 3–5 respectively. The Spanish energy regulatory authority (Comisión Nacional de Energía, CNE) publishes a monthly index of the LNG import prices in Spain, based on data declared at customs

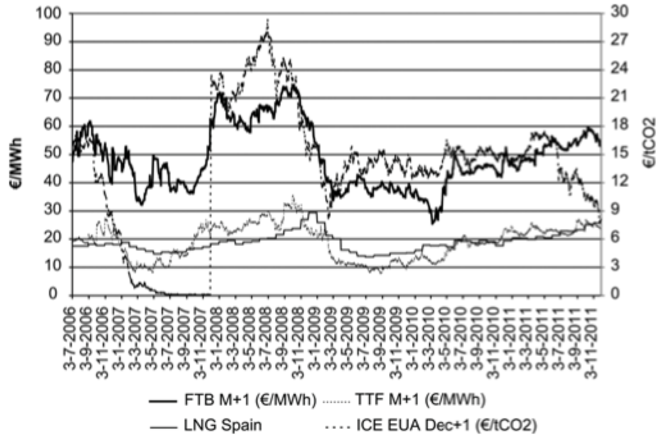

Fig. 3. Evolution of power (OMIP), gas (TTF), LNG import prices in Spain, and emission (ICE EUA) forward prices (month maturity). Sources: OMIP-OMIClear, Platts, ICE, and CNE.

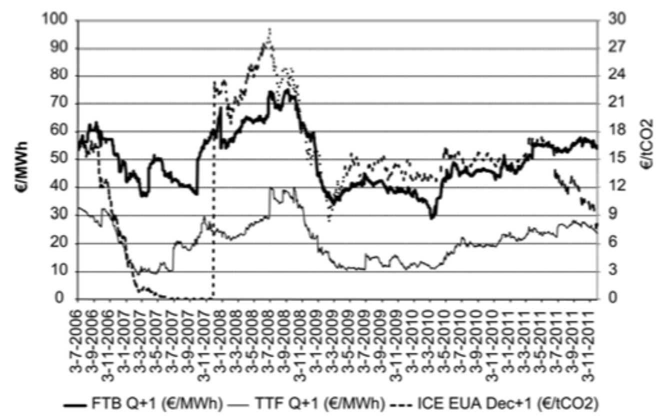

Fig. 4. Evolution of power (OMIP), gas (TTF), and emission (ICE EUA) forward prices (quarter maturity). Sources: OMIP-OMIClear, Platts, and ICE.

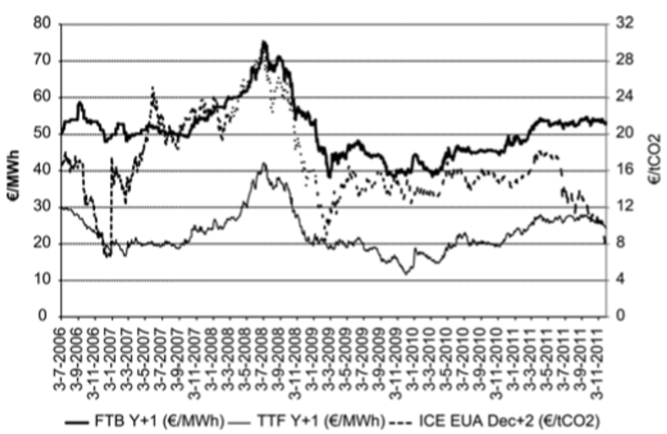

Fig. 5. Evolution of power (OMIP), gas (TTF), and emission (ICE EUA) forward prices (year maturity). Sources: OMIP-OMIClear, Platts, and ICE.

[32]. Reference [33] finds a co-integration relationship (monthly log prices) between such an index and the series built with the last 6 month average of Brent spot prices. This oil price rolling average, typically used in long-term gas contracts, is employed in the Spanish last resort tariff for natural gas. Fig. 3 includes the LNG series.

The jump in the emission prices during 2007 is due to the pass from the first phase of the EU ETS (years 2005–2007) to the second phase (years 2008–2012). The year and quarter gas prices are higher than the month gas prices during the summer of 2008, as the contract with larger maturity were more influenced by the record in oil prices (on July 3, 2008 the Brent crude oil price reached 144.22 \$/Bbl for the spot price and 147.05 \$/Bbl for the $\mathrm{M}+3$ futures contract). The EUA $\mathrm{Dec}+2$ contract is used for calculating the clean spark spreads—see section C below—for the 4th quarter contracts and for all the year contracts. Therefore, Fig. 5 shows the evolution of EUA $\mathrm{Dec}+2$. For computational simplicity, the daily values for EUA $\mathrm{Dec}+2$ are assumed to be equal to EUA $\mathrm{Dec}+1$ during the trading sessions in December (i.e., the December month contract of the prompt year is considered in both cases). The EUA $\mathrm{Dec}+2$ prices have always been bigger than EUA $\mathrm{Dec}+1$ prices in the considered period (on average only 3.4% bigger and showing a correlation of 0.99, discarding the trading sessions in December, due to the assumption aforementioned, and during the period 2 January 2007–30 November 2007, in which the EUA $\mathrm{Dec}+1$ was almost nil as previously stated).

TABLE III

DICKEY-FULLER'S TEST FOR ANALYSIS OF UNIT ROOT VARIABLES IN ENERGY LOG PRICE SERIES. SOURCES: OMIP-OMICLEAR, PLATTS, AND ICE

	OMIP M+1 (daily)	Brent M+1 (daily)	TTF M+1 (daily)	6 month Average Brent Spot (monthly)
Neither Intercept nor Trend	-0.182	0.338	-0.14	-0.084
p-values	>>0.1	>>0.1	>>0.1	>0.1
Only Intercept	-2.65	-1.33	-2.026	-3.163
p-values	0.08	0.62	0.28	0.02
Trend	-2.613	-1.893	-2.09	-3.369
p-values	0.27	0.66	0.55	0.06
Diagnosis	I(1)	I(1)	I(1)	I(1)

B. Co-Integration Analysis of Energy Prices

Co-integration analyses of energy logarithmic price series are done running Stata and E-views statistical packages. Table III shows the results of the Augmented Dickey-Fuller's test for the existence of unit root variables of times series for log daily prices of OMIP $\mathrm{M}+1$, Brent $\mathrm{M}+1$, and TTF $\mathrm{M}+1$. Log monthly prices of average Brent spot prices in the last 6 months are also analyzed as such structure is used in the Spanish gas last resort tariffs and in long term gas contracts [33]. The null hypothesis for existence of unit root is rejected at a significance level of 1% or less, otherwise the null hypothesis cannot be rejected and the series is diagnosed as non-stationary. The number of lags in the Augmented Dickey-Fuller's test is determined following Perron's criterion. The monthly Brent built with 6 average month spot prices is seasonally adjusted. Although this variable presents low p-values, the existence of unit root cannot be rejected. The same unit root test has been applied to the first difference of the variables in Table III. In all those cases the null hypothesis of unit root is rejected. Therefore all the series in Table III are non-stationary series whose first difference is stationary (I(1)).

Table IV shows the co-integration results based on unitary root analysis for the residue of the regression for OMIP $\mathrm{M}+1$ as dependent variable. Three regressions are built in which the single independent variables are Brent $\mathrm{M}+1$ (daily), TTF $\mathrm{M}+1$ (daily) and Brent spot 6 month rolling average (monthly, thus OMIP $\mathrm{M}+1$ monthly average is used as a dependent variable in its regression). The number of lags in the Augmented Dickey-Fuller's test was determined following Perron's criterion. Co-integration relationships between daily OMIP $\mathrm{M}+1$

TABLE IV

UNITARY ROOT ANALYSIS OF THE RESIDUE IN REGRESSION OMIP $\mathbf{M+1}$ VERSUS FUELS IN COLUMNS. SOURCES:OMIP-OMICLEAR, PLATTS, AND ICE

	Brent M+1 (daily)	TTF M+1 (daily)	6 month Average Brent Spot (monthly)
Neither Intercept nor Trend	-2.805	-4.466	-4.748
p-values	<0.01	<<0.01	<<0.01
Only Intercept	-2.804	-4.465	-4.707
p-values	0.0576	0.0002	0.0001
Trend	-2.944	-4.708	-4.914
p-values	0.1483	0.0007	0.0003
Diagnosis for the Residue	I(1)	I(0)	I(0)
Diagnosis for the Variable	I(1)	I(1)	I(1)
Co-integration	No	Yes	Yes

TABLE V

REGRESSION RESULTS OMIP $\mathbf{M+1}$ VERSUS FUELS SHOWN IN COLUMNS. SOURCES: OMIP-OMICLEAR, PLATTS, AND ICE

	Brent M+1 (daily)	TTF M+1 (daily)	6 month Average Brent Spot (monthly)
Beta	0.40	0.51	1.09
Error of Beta	0.02	0.01	0.04
R^2 (adjusted)	0.19	0.64	0.93

and daily TTF $\mathbf{M+1}$ and between monthly OMIP $\mathbf{M+1}$ and monthly Brent spot 6 month rolling average are found.

Table V shows the regression results for the 3 cases analyzed in Table IV. Only the regressions built with TTF $\mathbf{M+1}$ prices and with 6 month rolling average Brent Spot prices show significant $\mathbf{R^2}$ statistics (0.64 and 0.93, respectively). The co-integration results explain that electricity forward prices, due to the key role of CCGT as marginal cost technology in the Spanish electricity spot price, are influenced by the gas forward prices of the most liquid reference in continental Europe, and by the oil indexed prices used in long-term gas contracts and in Spanish gas last resort tariffs.

C. Analysis of the Clean Spark Spreads With Forward Prices

The Clean Spark Spreads (CSS) serve the power sellers to analyze if the gas fired generation is profitable and help to determine the proper power and gas hedges. They also serve the energy regulators to monitor if the electricity forward prices are directly influenced by the gas prices, and in case of remarkable divergences, to check if some market anomaly has occurred—e.g., excessive derivatives speculation or market abuse—in the scope of the European Regulation on Energy Market Integrity and Transparency, known as "REMIT", in force in December 28, 2011 [34]. The CSS, for each maturity ($\mathbf{M+1}, \mathbf{Q+1}$ or $\mathbf{Y+1}$), is obtained as the difference between the power futures price and the forward generation cost of a gas combined cycle, as expressed in (2):

$$CSS = P_{Power} - ((P_{Gas} \times \eta_{CCGT}) + (P_{CO2} \times E_{CCGT})) \quad (2)$$

where "CSS" is the Clean Spark Spread, "P_{Power}" is OMIP power futures price, "P_{Gas}" is TTF forward gas price, "η_{CCGT}" is the CCGT thermal efficiency, "P_{CO2}" is the emission futures price, and "E_{CCGT}" is the CCGT emission rate (in t_{CO2}/MWh). The CCGT forward generation cost is calculated as the sum of the gas forward price—divided by the thermal efficiency of the power plant—and the price of the $\mathbf{CO_2}$ allowance multiplied by the emission rate. A CCGT thermal efficiency of 55% and an emission rate of $\mathbf{0.37\ t_{CO_2}}$/MWh are employed [3].

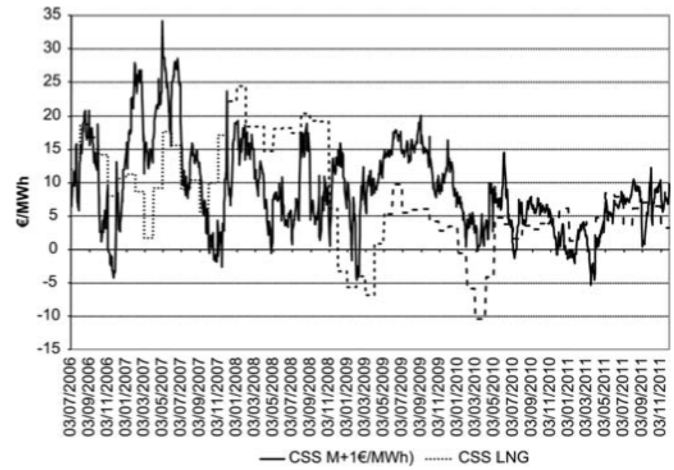

Fig. 6. Daily evolution of CSS built with $\mathbf{M+1}$ power and gas contracts and Spanish month LNG index. Sources: OMIP-OMIClear, Platts, ICE, and CNE.

Fig. 7. Daily evolution of the CSS built with the prompt quarter power and gas contracts. Sources: OMIP-OMIClear, Platts, and ICE.

Figs. 6–8 show the daily evolution of the resulting CSS for the prompt month, quarter and year power and gas contracts according to (2). Fig. 6 also shows the CSS for the LNG index. This CSS is built assuming a price charge of 5% in terms of third party access rates (regasification and transportation to the Spanish virtual trading point) and related to OMIP $\mathbf{M+1}$ series. Whereas the largest positive spreads are found for prompt month contracts, the largest—and more frequent—negative spreads occur for prompt year contracts. The influence of high oil prices on gas prices is bigger for the prompt year gas contracts, as these contracts show the largest correlation with oil prices (Table II). In the 3rd quarter of 2008 and the 1st half of 2010, the $\mathbf{CSS_{LNG}}$ are negative whereas the $\mathbf{CSS_{M+1}}$ are positive. The remarkable differences of both spreads indicate the strategic role of a balanced gas portfolio structure for utilities in their gas procurement through oil indexed contracts and in gas hubs.

Table VI shows a comparison of the clean spark spreads for the prompt month, quarter and year maturities, and for the spreads built with Spanish LNG monthly index, providing

Fig. 8. Daily evolution of the CSS built with the prompt year power and gas contracts. Sources: OMIP-OMIClear, Platts, and ICE.

TABLE VI
COMPARISON OF ANNUAL AVERAGE CSS PER MATURITY ("$M+1$", "$Q+1$", "$Y+1$") AND CSS BUILT WITH SPANISH LNG MONTHLY INDEX. SOURCES: OMIP-OMICLEAR, PLATTS, ICE, AND CNE. * DATA FOR YEAR 2006 SPAN FROM JULY3, 2006 TO DECEMBER31, 2006. ** DATA FOR YEAR 2011 SPAN FROM JANUARY3, 2011 TO NOVEMBER30, 2011

Year	CSS M+1 €/MWh	CSS LNG €/MWh	CSS Q+1 €/MWh	CSS Y+1 €/MWh
2006*	9.15	13.42	0.19	2.35
2007	14.91	11.55	13.79	6.65
2008	9.54	15.97	2.87	-1.96
2009	11.61	2.31	10.54	5.48
2010	4.71	0.89	5.66	3.54
2011**	4.80	5.19	3.08	-0.48
Average	9.12	8.22	6.02	2.60
Minimum	4.71	0.89	0.19	-1.96
Maximum	14.91	15.97	13.79	6.65

annual average values. The spreads tend to be positive, except for the year maturity, due to the existence of more frequent periods with negative spreads (Fig. 8). The smallest spreads are presented for year contracts, followed by quarter and month contract. Therefore gas fired generation companies can maximize profits in their forward trading with gas and power contracts of shorter maturity. The CSS built with LNG prices shows the amplest spread between minimum and maximum prices and become much smaller than CSS $M+1$ in 2009.

On the other hand, as found in [19] for OMIP power futures contracts, the forward risk premium of year contracts is bigger than for quarter contracts and even bigger than for month contracts, as the largest the maturity, more uncertainty is summed up to the forward price. In a situation of contango (forward prices bigger than spot prices), power trading with year contracts can produce larger profits for net sellers (i.e., companies whose open interest in forward markets tends to have a selling nature, e.g., generation companies).

VI. CONCLUSIONS

The evolution of the Iberian power futures market, which started operations on July 3, 2006, has to be seen together with the dominant OTC trading and the CESUR auctions in which the last resort suppliers purchase part of their regulated supplies. In all these forward contracting mechanisms, the forward price tend to be bigger than the resulting spot price in the delivery period, i.e., the ex-post forward risk premium is usually positive. As the forward risk premium is bigger for contracts with larger maturity (year contracts followed by quarter contracts), the market participants can benefit in many cases by means of trading short positions (i.e., keeping a selling net position) in such power contracts. Conversely, market participants with a natural long position (e.g., suppliers purchasing derivatives to hedge for their retail sales) might be more interested in trading month contracts, especially when the perception of uncertainty and thus energy risk is bigger. Since year 2011, the premium is smaller due to the existence of a regulatorily recognized price for coal power plants. However, smaller premia should be the natural result of a well developed and efficient power forward market, rather than the effect of artificial mechanisms distorting the price formation.

The power futures are strongly correlated with the European gas prices, especially between the year contracts, as far as the renewable forecasts—a key signal for including renewable generation costs in the electricity price formation—are currently accurate just on the very short term. Results from co-integration analysis for the Iberian prompt month power futures contracts with gas and oil prices show that such electricity prices are influenced by gas forward prices of the most liquid reference in continental Europe (TTF), and by oil prices (6 month rolling average of Brent spot prices) used in long-term gas contracts and in Spanish gas last resort tariffs.

The clean spark spreads for prompt futures contracts, obtained as the difference between the power futures price and the forward generation cost of a combined cycle gas turbine, tend to be positive. The biggest spreads are for the month contract, followed by the quarter contract and then by the year contract. Therefore, gas fired generation companies can maximize profits trading more frequently with electricity contracts of shorter maturity.

Both the forward risk premium and the clean spark spreads are key indicators for market participants to optimize their trading strategies—they can exploit arbitrage gains through trading with contracts of different maturity and perform cross-market hedging operations—and for regulatory agencies to monitor the fair price formation in the wholesale energy markets, that ultimately affects the end-user prices.

Further research is encouraged taking into account the influence of the dark spreads (obtained as the difference between the power futures prices and the generation costs of a coal power plant, the latter calculated, e.g., through coal futures contracts traded at the European Energy Exchange, EEX) to assess the influence of the coal generation—out of the regulatorily fixed prices—in the Iberian power forward price formation. A comparative analysis of both premia and spreads with other European markets (e.g., French, German, or Nordic) could be used to measure their different efficiency levels. As the current research is based on prompt base load contracts, the analysis could also be extended to further maturities (i.e., not immediately close to delivery) and for peak products.

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